

APPLICATION FOR UNITED STATES PATENT

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Invention: **STRENGTHENED, LIGHT WEIGHT CONSTRUCTION BOARD
AND METHOD AND APPARATUS FOR MAKING THE SAME**

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**STRENGTHENED, LIGHT WEIGHT CONSTRUCTION BOARD AND
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CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a Continuation-in-Part Application of copending U.S. Patent Application Serial No. 09/547,615, which application is a Continuation-in-Part Application of copending U.S. Patent Application Serial No. 09/471,448, which application is a Continuation-in-Part Application of copending U.S. Patent Application Serial No. 09/374,589, which application is based upon and gains priority from U.S. Provisional Patent Application Serial No. 60/139,618, filed June 17, 1999 by the inventor herein and entitled "Improved Wallboard and Method and Apparatus for Making the Same," and which application is also a Continuation-in-Part Application of U.S. patent Application Serial No. 09/195,438, filed November 18, 1998 by the inventor herein and entitled "Light Weight Fire and Moisture Resistant Wallboard."

BACKGROUND OF THE INVENTION

1. Field of the Invention.

This invention relates to new compositions and methods that are useful in the manufacture of boards or panels for use in construction applications. More particularly, this invention is directed to a novel construction board or panel composition comprising a unique combination of synthetic binders selected for their ability to establish a strengthened permanent bond in the final dry state, in combination with gypsum and an expanded mineral such as Perlite. Utilizing such synthetic binders provides an increased strength to the construction board core, enabling lighter-weight Perlite to replace at least a portion of the heavier gypsum traditionally used in construction board compositions. Moreover, the synthetic binders disclosed herein

1 uniquely cross-link with the expanded mineral to form a much stronger bond between the
2 constituent components of the construction board core material than that which has been
3 available in previously utilized or known construction board products. In a preferred
4 embodiment, the lightweight, strengthened construction board of the present invention also
5 comprises a covering veneer of paper or fiber that is treated to further the fire retardant and
6 moisture resistance of the product. Additionally, this invention relates to the unique
7 manufacturing process to produce the construction board composition of the present invention in
8 order to create a lightweight, strengthened, moisture resistant, and fire retardant panel to be used
9 in construction applications.

10 11 2. Description of the Background

12 It is well known in the art to use planar panels or sheets formed from inorganic materials
13 in the construction of walls, ceilings, floors, exterior sheathing, and similar construction
14 elements, instead of applying wet plaster to such surfaces. Such panels may be applied to stud
15 work comprising the walls, ceilings, floors, and exteriors of building structures in the form
16 wallboard, lath, sheathing, and the like, using nails, screws, or other fastening means. The use of
17 calcium sulfate hemihydrate $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ in the manufacture of such construction panels has
18 predominately been unchanged for over half a century. In general, these panels comprise
19 essentially a core of set interlaced gypsum crystals disposed between fibrous, especially paper,
20 liner sheets. After the gypsum slurry has set (i.e., reacted with the water from the aqueous
21 slurry) and dried, the sheet is cut into standard board sizes.

22 Unfortunately, however, traditional gypsum construction boards can be quite heavy,
23 causing quick fatigue to installers and delayed construction schedules, as well as large

1 transportation costs. Likewise, traditional construction boards often realize significant increases
2 in weight when particular construction applications require stronger construction panels, thus
3 making their use even more problematic.

4 Attempts to modify the composition of traditional gypsum panels in order to provide a
5 lighter weight construction panel have been made, but with little success or commercial viability.
6 For example, the addition of synthetic binders has very recently been attempted as disclosed in
7 U.S. Patent No. 5,879,825 to Burke et al.; however, the engineering and chemical research in
8 various combinations of complex chemical formulations and combinations thereof has been quite
9 limited. Additionally, Burke et al. fails to address the environmental concerns of noxious fumes
10 under fire engineering standard ASTM testing E119. Still further, cost considerations limit the
11 amount of acrylic polymer present in the Burke et al. composition to 1 to 2 percent, but the fact
12 that such acrylic polymer in Burke et al. employs a less than 10% solids ratio results in a
13 polymer having a minimal cross-linking performance with the other constituent elements.
14 Further, while the use of Perlite as an antidesiccant to prevent the dehydration of gypsum crystals
15 formed during setting of the core composition is disclosed, no consideration is given to
16 introducing an expanded mineral, such as perlite, as a substitute for gypsum as one of the
17 structural foundations of the board core and as a strengthening agent when combined with
18 appropriate other constituent elements (as set forth below), nor the specific need for a synthetic
19 binder composition for establishing a complete cross-linking between the constituent elements of
20 the core in order to create a molecular change within the strengthening agent, which molecular
21 change is in turn required to completely bond a reduced amount of gypsum with the other
22 components of a construction board core.

1 It would therefore be highly advantageous to provide an improved, high strength,
2 lightweight construction panel product which reduces the need for gypsum in the panel
3 composition by means of displacing some of the normal amount of gypsum utilized with the
4 expanded mineral perlite, and which utilizes a synthetic binder composition that enables a
5 complete cross-linking of the constituent elements of the lighter construction panel core to form
6 a rigid structure with the structural integrity to withstand the structural requirements of
7 traditional construction panels. Such construction panels should meet industry requirements, and
8 likewise have a strength at least equal to previously known construction panels while reducing
9 the weight of the finished panel.

10 11 4. Summary of the Invention.

12 It is therefore an object of the instant invention to provide an improved, light weight,
13 strengthened gypsum construction board product that overcomes the disadvantages of the prior
14 art.

15 This and other objects are achieved through a composition consisting essentially of a
16 unique combination of synthetic binders selected for their ability to establish a permanent bond
17 in the dry state, combined with an expanded mineral (e.g., Perlite and crushed Perlite), organic
18 binding adhesives, drying agents, crystal growth enhancers, and gypsum with a sufficient
19 amount of water to form an aqueous slurry, all contained within a covering of treated moisture
20 and heat resistant paper material, which produces an improved lighter-weight, strengthened
21 gypsum construction board product. The technology of the present invention utilizes an
22 expanded mineral which fuses with the calcined gypsum mineral and physically becomes part of

1 the composite matrix due to the complex formulation of binders and gypsum attaching
2 themselves to the expanded mineral, instead of the expanded mineral only acting as a filler.

3 Perlite (expanded) can be graded by density in pounds per cubic foot, and classified by
4 product number or trade name for producer and user identification. The expanded product can
5 weigh as little as 2 pounds per cubic foot, but the most widely used bulk-density grade range is
6 from 7 to 15 pounds per cubic foot. The range of expanded Perlite utilized in the construction
7 board composite core of the present invention is ^{3 to 10} ~~4 to 10~~ pounds per cubic foot, with 4 pounds per
8 cubic foot being preferred. It has been found that the more friable cryogenic and micro-sphere
9 grades in the 3 to 4 pound range are favorable, with 4 pounds being the most preferred, over the
10 heavier grades ranging from 5 to 10 pounds per cubic foot. Grades typical to this heavier range
11 include concrete, plaster, and cavity fill or masonry, which can also be utilized, but are not as
12 preferable as the lighter previously mentioned grades. The particle size ranges from 100 to 2,000
13 microns, and preferably from 200 to 1000 microns. Preferably, the expanded Perlite will have a
14 particle size ranging from no larger than 10 mesh sieve size and no smaller than 200 mesh sieve
15 size measured on standard screen scale. The particle size of the preferred expanded Perlite is
16 directly related to the strength of the construction board core in the aspect of fusion. Particles
17 that are too large tend to space gypsum crystal growth too far apart, and particles that are too
18 small do not allow enough area for the gypsum crystal to fuse onto. The particle size is not
19 directly related to the expansion method but can be controlled by means of properly sizing the
20 Perlite ore prior to expansion.

21 It was determined to be advantageous to use a polyvinyl acetate emulsion or vinyl acetate
22 homopolymer emulsion or water based non-V.O.C. acrylic or polyurethane emulsion for use in
23 the binder of the instant invention. While vinyl acetates of all types were found to be less costly

1 and performed well, vinyl acetate emulsions with 0.10% to 30% polyvinyl alcohol were further
2 preferred and found to provide unforeseen benefits over powdered polyvinyl acetates. First,
3 vinyl acetate emulsions containing polyvinyl alcohol are available at far less cost (approximately
4 one third) than powdered polyvinyl acetates. Further, vinyl acetate emulsions when properly
5 added and diluted for quick dispersion in the metered water or water solution feeds, prior to
6 entrance into the gypsum slurry mixer, dispersed and performed better than powdered polyvinyl
7 acetates, thus simplifying the manufacturing process and reducing costs caused by flawed
8 boards. Better results in terms of reactivity, dispersion, and ease of mixing occurred in test
9 samples when the vinyl acetate emulsions were strengthened and stabilized with polyvinyl
10 alcohol. It was discovered that the optimum molecular weight of the preferred polyvinyl alcohol
11 selected to strengthen and stabilize the vinyl acetate emulsion is a function of the type of gypsum
12 stucco prepared, and the length of time the final vinyl acetate emulsion needed to be stabilized.
13 In final prepared gypsum stuccos that had higher percentages of certain clays (i.e., above 1% of
14 clays commonly found in some gypsum deposits) naturally occurring in or with the gypsum ore,
15 lower molecular weight polyvinyl alcohols, preferably between 20 and 5000, exhibited better
16 results with less initial thickening of the wet gypsum slurry mix.

17 It has also been determined that the addition of small amounts of accelerators or
18 strengthening agents described below can be added to the final polyvinyl acetate emulsion to
19 increase strength and final composite set performance. To describe this macroscopically, the
20 binder is diluted in the processed water to disperse throughout the wet gypsum and perlite slurry
21 in the pin mixer. An accelerator or strengthening agent is added to the back side of the gypsum
22 slurry pin mixer, to begin to chemically increase the set of the binder once the formed
23 construction board is proceeding downstream to the rotary knife. Optimally, the initial set time of

1 the board is decreased such that the board can be cut in less time. Thus, the board line can be run
2 faster, producing more construction board in a shorter period of time. Potassium or other alkali
3 elements or compounds can be added at 0.001% to 3% of the total board wet weight at the last
4 stages to increase the rate of the set time of the binder and ultimately decrease the initial set of
5 the construction board. While Potassium Sulfate has been utilized to decrease the initial set time
6 of the green construction board prior to the knife, too high or too small amounts can actually
7 burn the gypsum crystals and create a "punky" or powdery final construction board that has lost
8 its strength. The binder (vinyl acetate emulsion, or water based non V.O.C. acrylic or
9 polyurethane emulsion) reacts with the accelerator (potassium sulfate) to retard or even eliminate
10 the burning of the gypsum crystals.

11 Optionally, reinforcing fibers, fire retardants, water repellents, and other water proofing
12 materials may be part of the composition. More particularly, current gypsum construction board
13 core formulations, once dried, have common micro-cracks, form more brittle core composites,
14 and exhibit less tolerant processed board flexibility. Paper fibers, or other synthetic fibers, have
15 been utilized more in the past to hold the core composite together, yet have been insufficient to
16 stop board drying over time, and increase short and long term micro-cracking and ultimate core
17 breakdown or spot load failure. Thus, the development of the synthetic adhesive technology of
18 the instant invention has developed critical improvements to board flexibility, moisture retention,
19 and long term, sustained and improved strength.

20 Actual plant manufacturing test runs of the construction board compositions described
21 herein were conducted for several hours each, and using a variety of gypsum ore and gypsum
22 stucco preparation methods. The test runs showed improved ASTM test results at each run. The
23 process of introducing and adding sufficient amounts of the synthetic binder into the final

1 gypsum stucco was successfully completed during each test run. However, improved results
2 occurred when the binder was diluted in the metered water or other prepared water solutions, for
3 direct feed prior to the gypsum slurry mixer. Higher ASTM lab test results occurred when
4 utilizing the optimum design combinations and percentages set forth in the examples below of
5 vinyl acetate and water based non-V.O.C. acrylic or polyurethane emulsions, with each particular
6 type of gypsum stucco supplied during the test runs. Thus, by optimizing the final polyvinyl
7 acetate homopolymer or water based non-V.O.C. acrylic or urethane polymer emulsion,
8 optimum test results were achieved in both the test lab and in actual manufacturing test samples.

9 Thus, the test run results showed that the construction board composition of the instant
10 invention provides a number of benefits over previously known construction board products.

11 First, the present invention allows for a construction board composition that is
12 significantly lighter in weight (up to fifty percent lighter) than current traditional heavy gypsum
13 construction board formulations. This reduced weight also results in transporting lighter loads,
14 in turn reducing transportation costs. Further, job site labor costs are reduced by enabling the
15 workers to handle lightened loads, such that the installation process is made easier and less
16 costly. Similarly, the potential for heavy board related injury accidents to the tradesmen that
17 install the construction board product is reduced.

18 Further, the construction board composition of the instant invention exhibits equal or
19 greater strength than current heavy gypsum construction board, with improvements in moisture
20 resistance and flame resistance that exceeds current industry standards. This lightweight and
21 strength factor equates to decreased structural support load bearing and lessens the total support
22 strength required in any project, in turn further reducing overall construction costs.

1 Yet another benefit of the strengthened construction board of the instant invention is the
2 reduction in the amount of board breakage (and in the amount of airborne particulates associated
3 with such breakage) and losses due to manual or machine transport to the installation site, due to
4 the fact that the composition of the instant invention provides the construction board with greater
5 flexibility than has been known in previous construction board compositions.

6 Yet another benefit of the composition utilized in the instant invention is the "clean-snap"
7 characteristics exhibited by a finished construction board when the board is cut with a utility
8 knife. The attempted addition of synthetic binders in the past to construction board compositions
9 have reduced the ability to cut the finished construction board sheet during installation with a
10 utility knife. However, the composition of the instant invention was developed after extensive
11 testing and analysis of numerous chemical combinations, with extensive chemical technical
12 research and testing to realize a brittle cross-linking complex polymer that combines and fuses
13 with the mineral and expanded mineral, that is easily cut and snapped with a utility knife as
14 applied in standard construction industry use.

15 The specific binders described below as a constituent element of the compositions used
16 herein also provide specific benefits related to the characteristics and manufacturing economics
17 of the construction board of the instant invention. Water based vinyl acetate, non-V.O.C acrylic
18 and non-V.O.C. polyurethane emulsions tested were selected and preferred over other
19 petrochemical-based emulsions or liquid plastics for several specific reasons. First, the most
20 crucial practical factors in selecting the preferred type of adhesive are performance of the
21 adhesive in binding the construction board core, and cost relative to that performance, and the
22 compatibility of the particular emulsion with the other specific constituents of the sheathing core.

23 Such cost factors include both the cost of the base components, such as vinyl acetate

1 monomer (VAM) (which today is preferably produced from ethylene) that make up the adhesive,
2 and the cost to make the final product. It was found that vinyl acetates provide the lowest cost,
3 while water based non-V.O.C. acrylic and polyurethane polymers provided non-toxic and
4 environmentally safe high performance at a slightly higher but not unreasonable cost, while all
5 three maintained assurance of high adherence and coherence capabilities to attach to the minerals
6 in the construction board core, namely, gypsum and/or perlite. Also, a deliberate effort was
7 made to determine and utilize a low cost, final stage, brittle-type plastic in emulsion or liquid
8 initial state, that when hardened would have the ease of a clean snap when cut with a utility
9 knife. It was discovered that the vinyl acetate adhesive family and the non-V.O.C. acrylic and
10 polyurethane families performed superior to sodium silicates in meeting these requirements, even
11 though sodium silicates were lower in overall cost.

12 Regarding the compatibility of the emulsion with the other constituents of the
13 construction board core, test results proved that water solubility of the adhesives and ease of
14 dispersion into the final core composite was crucial to fabricating the construction board without
15 paper blows and peels due to insufficient or improper re-hydration of the calcined gypsum. In all
16 of the tests performed, results showed favorably toward the latex water based emulsions for the
17 best compatibility and ease of dispersion when added into the system with no adverse affect on
18 hydration. The preferred polymer systems of the instant invention provided for complete
19 hydration of the gypsum as well as improving upon the paper to core bond in every instance of
20 its use. The latex water based emulsions also worked best at the drier end of the line (in the kiln)
21 as they didn't react poorly or inhibit evaporation due to filming and/or agglomeration and
22 blistering due to improper dispersion into the slurry.

1 Also, it was discovered that board flexibility during actual board installation, or during
2 the manufacture of the board as it travels over rollers and curved rises in and out of the drying
3 kilns, was improved through the use of more plastic adhesives (such as vinyl acetate and non-
4 V.O.C. acrylic and polyurethanes) as the binder.

5 Yet another benefit of the binder formulations utilized in the construction board of the
6 instant invention lies in their ability to easily cross link with the other constituent elements of the
7 formulations provided below. Vinyl acetates were found to react well and cross-link in the
8 presence of boron with starches to create a final tacky binder, at the proper percentages set forth
9 below, that forms a brittle plastic excellent for binding the core of the construction board product
10 in such a way as to maintain superior strength characteristics while reducing the overall weight
11 of the board.

12 The improved, strengthened core material of the instant invention also provides increased
13 compression, shear, and tension loading test results in comparison with the conventional non-
14 reinforced gypsum construction board. ASTM Test Standard C79 standard specifications for
15 gypsum construction board require that specimens shall surpass an average surface water
16 absorption of not more than 1.6g after 2 hours of elapsed time (Section 5.1.7). While gypsum
17 construction board is required to meet the above ASTM standards, moisture resistance and
18 adverse weather conditions have been long-term problems with gypsum board. The improved
19 gypsum board of the instant invention comprises an improved moisture resistant cover and core
20 material that far surpasses ASTM C79-5.1.7. Thus, the present invention improves the structural
21 strength, moisture resistance, and weight factors in the design of a new improved gypsum board
22 to be utilized as a construction material.

1 Gypsum board manufacturing is a complex process from the collection of the gypsum
2 rock to the production of the completed construction board. However, the improved gypsum
3 construction board product of the instant invention, as described more fully in the examples
4 below, offers yet another benefit over previously known construction board products, in that it
5 provides increased production capacity from a given gypsum supply over traditional gypsum
6 products and methods of manufacture. More particularly, the technology of the present
7 invention allows for decreased set times from the pin mixer to the knife in laboratory testing,
8 which in turn increases boardline manufacturing speeds far beyond what is currently being
9 realized. As manufacturing speeds increase, so does production, enabling greater amounts of
10 construction board to be produced to meet the current demand. This complex formulation of
11 binders can be seen to be utilized in a wide variety of other building materials as well.

12 Yet another improvement of the gypsum construction board product of the present
13 invention comprises the environmental improvements realized through the use of the specific
14 binders recited herein. Environmental factors must be evaluated when selecting the preferred
15 adhesive, such as noxious fumes emitted in burning test samples and kiln stack emissions while
16 heating and drying the board during the manufacturing process. Plant operational environmental
17 concerns and plant kiln stack emissions are critical factors for manufacturers to consider in
18 evaluating the use of synthetic adhesives. Petrochemical-based acrylics exhibited higher stack
19 emissions, noxious fumes in burn tests, and presented more environmental operational concerns
20 over similar percentages of vinyl acetate emulsions and water based non-V.O.C acrylics and
21 polyurethanes. Further, the specific adhesives used in the construction board product of the
22 instant invention provide a reduced half-life over commonly used adhesives. The adhesives used
23 in the construction board product of the instant invention decompose very quickly and easily.

1 Thus, the improved construction board of the present invention provides a lightweight,
2 strengthened, fire retardant, whitish-covered Perlite and gypsum construction board with
3 environmental improvements that is competitively priced to traditional gypsum construction
4 board products.

5 A preferred embodiment of the invention is further directed to a method and apparatus for
6 producing expanded Perlite and gypsum construction boards of a thickness not less than ¼ inch
7 and not greater than 1 inch comprising the steps of: adding starch, boric acid, foamer, gypsum,
8 and a latex polymer emulsion of vinyl acetate or water based non V.O.C. acrylic or polyurethane,
9 with water to expanded Perlite to form a composition; the aqueous slurry of settable Perlite is
10 enveloped between two high quality paper cover sheets comprised of recycled virgin pulp and
11 formed into a board; directing the continuous board away from the forming apparatus to a cutting
12 knife where it is cut to desired length; and finally drying the board in a high temperature kiln at
13 temperatures ranging from 75°C to 325°C. Optionally, the process further includes the steps of
14 forcing hot air to an encapsulated section of board line, starting the curing process prior to the
15 board reaching the board cutting knife.

17 **BRIEF DESCRIPTION OF THE DRAWINGS**

18 Other objects, features, and advantages of the present invention will become more
19 apparent from the following detailed description of the preferred embodiment and certain
20 modifications thereof when taken together with the accompanying drawings in which:

21 FIGURE 1 is a schematic view of the perlite processing arrangement of the instant
22 invention.

FIGURE 2 is a schematic view of the perlite wallboard production facility of the instant invention.

DETAILED DESCRIPTION OF THE INVENTION

The preferred composition of the improved gypsum construction board product of the present invention comprises a binder especially selected for the property of permanent tackiness in the dry state, preferably a self-crosslinking permanently tacky polymer, and more particularly includes a starch, boric acid, vinyl acetate emulsion or water based non-V.O.C. acrylic or polyurethane emulsion, perlite, and gypsum. It has been found that this combination (in the proportions set forth below) offers the best results for weight, strength, setting and bond of the construction board core. After applying and analyzing a wide variety of adhesives by themselves and in combination with one another, it was determined that a binder having the composition set forth herein would allow the construction board to perform as closely to what is currently used while adding strength and reducing weight.

The strengthened core of the improved gypsum construction board of the instant invention contains expanded Perlite in the range of 0.5 to 60% volume by weight. The expanded Perlite ranges in sizes from 100 to 2000 microns, and preferably from 200 to 1000 microns. The following is a typical sieve analysis of the preferred grade: 11.5% retained on 16, 39.1% retained on 30, 24.3% retained on 50, 12.9% retained on 100 and 2.8% retained on 200. The preferred grade loose density ± 1 pound is 4 pounds per cubic foot and has a compacted density of 5.5 pounds per cubic foot. Hard Perlite ore having a high compaction resistance is a very dense concentric ore located within the inner perlitic dome, while softer, low compaction resistant ores are located in the frothy pumicious outer surface of the perlitic dome and are very friable. The

1 expanded Perlite utilized in the construction board of the instant invention is preferably derived
2 from classical concentric granular ores from the middle of the perlitic dome, which ores are able
3 to achieve densities in the 4 to 8 pound range, in order to minimize the expanded density and
4 weight of the Perlite used in the composition of the instant invention while maximizing its
5 strength. While Perlite has been used in the past in small quantities as a filler or additive in
6 gypsum board compositions, the instant invention utilizes expanded Perlite as part of the
7 composite core, adding strength to the core as the binder grabs onto the Perlite.

8 The combination of starch, boric acid and vinyl acetate or water based non-V.O.C.
9 acrylic or polyurethane emulsion in itself is sufficient to bond the Perlite together in producing
10 the composite core of the instant invention. However, the combination of gypsum and perlite in
11 the formulation of the improved construction board product of the instant invention, in
12 comparison to other cementitious materials, is preferred due to excellent compatibility of the
13 components described herein.

14 It is important to note that the unique adhesive technology that is described below is
15 completely new and unobvious to the manufacture of construction board products. This process
16 adds a synthetic variable into an already well-used natural adhesive formulation of starch and
17 borate. When starch is treated with borate, interchange linkages are formed throughout the
18 borate anion structure resulting in modifications of the physical properties of the polymer
19 system. The overall result is a binder which, during the construction board manufacturing
20 process, undergoes a chemical change which provides for complete crosslinking between the
21 starch, borate, and synthetic adhesive to form a strengthened web for gripping the gypsum and
22 perlite and forming a rigid core.

1 Starch and borate are often added to the traditional construction board composition in
2 order to protect the delicate gypsum crystals and to ensure proper crystal growth of the gypsum
3 constituent of the construction board core as the board is heat treated in a drying kiln at extreme
4 temperatures. However, as mentioned above, starch and borate also combine to form a natural
5 adhesive. Traditional gypsum compositions do not utilize an additional binder to give the board
6 strength, but rather rely on gypsum crystal growth brought about by heat treatment of the board
7 in its final manufacturing stage. Thus, traditional gypsum construction board compositions do
8 not rely on the adhesive nature of the combination of starch and borate. Borate is not utilized as a
9 standard constituent in all construction board core formulations in the industry, but is preferred
10 by some and is always added to fire rated board formulations as a fire retardant.

11 The construction board composition of the present invention, however, does require an
12 additional binder. It has been found that adding another polymer, namely a vinyl acetate
13 emulsion or water based non-V.O.C. acrylic or polyurethane emulsion, to the starch polymer and
14 boric acid enables a cross-linking to occur between the three constituents. By crosslinking the
15 synthetic polymer chain with the starch and borate polymer chain, more extensive chemical
16 changes are brought about. On a molecular scale, the polymer chain branches extend in all
17 directions, attaching to the gypsum and perlite and increasing the overall strength of the board.

18 Cross-linking of the binder utilized in the present invention with the starch polymer chain
19 is brought about through boron or the use of boric acid. It was originally believed that the
20 commonly used compound boric acid was a sufficient source of boron for the process of the
21 present invention to cross-link the hydroxyl groups of the starch with the vinyl acetate emulsion
22 branch polymer chains. However, large scale test runs of the construction board of the instant
23 invention revealed an occasional high water demand when standard technical grade ortho boric

1 acids were used, especially when introduced into the system in solution as is not uncommon in
2 board production. Laboratory testing revealed that the pH of the boric acid (6.1 in 0.1% solution)
3 and its low molecular weight were causing some fluidity decrease or viscosity increase in slurry
4 formation. In these circumstances, the solution is to replace the boric acid with sodium
5 tetraborate pentahydrate (5 mol) or sodium tetraborate decahydrate (10 mol), the two compounds
6 actually being less costly than the ortho boric acid. The amount of borax or boric acid should be
7 limited in the range of not higher than 0.35% of the total wet weight of the final slurry or more
8 specifically not more than 0.1% of the total amount of synthetic binder utilized (by weight), as it
9 has been found that higher concentrations can cause gelling of the polyvinyl acetate emulsion
10 and affect strength.

11 The particular type of board starch utilized is yet another important consideration.
12 Starches, or more specifically unmodified cereal flours and modified corn starches, are
13 commonly utilized in gypsum board production to provide a better interface between the paper
14 and the core and to protect the gypsum crystal during drying of the board, as well as to allow for
15 increased paper bond. A large number of starch grades can be utilized from lower grade cereal
16 flour to high grade very thin boiling starches which are acid treated. Gelling and flow properties
17 as well as compatibility are better in the higher-grade starches produced from dent corn. The
18 quantity utilized in standard construction board production can range anywhere from 5 to 12
19 pounds per thousand square feet (MSF). Typically this range is from .20 to .50 percent of the
20 wet board weight (MSF). Testing conducted in the laboratory showed better resulting strength
21 development using the formulation of the present invention and starch in the range of 0.30 to
22 0.75 percent by weight (MSF) in combination with the synthetic binder. Higher grade acid
23 modified starches worked well in combination and to cross-link with the vinyl acetate emulsion.

1 Further testing revealed other types of starches, including oxidized thin boiling starches, worked
2 well if not better than acid modified starches. In some situations, oxidized starches are highly
3 compatible with vinyl acetate emulsions as are acid treated starches. But in situations where the
4 gypsum stucco has clay impurities, the oxidized starch can grab onto the vinyl acetate emulsion
5 and block flocculation of clay particles with the polyvinyl alcohol, virtually eliminating "clay
6 shock" and viscosity problems experienced in formulations where clay shock occurs. Although
7 slightly higher in cost, oxidized starches are believed to be the least expensive and simplest
8 solution in these clay situations. The gelling and fluid characteristics of starch play a larger role
9 in the formulation of the present invention than in standard construction board formulations.
10 Instead of the majority of the starch migrating to the face to protect the core to paper bond, much
11 of the starch is retained in the core to chemically combine with the synthetic additive to fuse the
12 minerals together. This cross-linking of the starch and synthetic additive is key to the strength
13 development of the core of the lightweight construction board of the present invention. In all
14 tests, the higher grades, meaning flash dried, wet milled modified starches gave the best results
15 in nail pull and flexural strength ASTM testing procedures over the lower grade, dry milled, belt
16 dried starches requiring less processing than higher grade starches. The use of more intensely
17 processed starches is somewhat a factor to consider in determining the optimum final
18 construction board costs.

19 By introducing vinyl acetate, polyvinyl acetate copolymer, or a vinyl acetate-ethylene
20 copolymer, or water based non-V.O.C. acrylic or polyurethane polymer into the compositions of
21 the construction board of the instant invention, the resultant complex molecule is much larger,
22 extending its various branches in all directions. It is this desirable change in the polymeric
23 structure of the molecule to a more highly branched chain polymer of higher molecular weight

1 that produces an adhesive with increased viscosity, quicker tack, and better fluid properties.
2 These qualities are crucial to the strength of the most preferred embodiment of the invention.
3 Listed below are two main benefits of this polymer adhesive system. First, increased flexural and
4 compressive strength is realized over current gypsum board ASTM standards. Secondly, the
5 unique polymer adhesive composition of the instant invention enables a construction board
6 composition that is up to as much as fifty percent lighter than current gypsum board.

7 The vinyl acetate emulsion used as the binder in one embodiment of the instant invention
8 produces very favorable test samples and test results. The vinyl acetate emulsion is a milky white
9 liquid, with typical characteristics in the range of a melting point of 32°F to 39°F, a vapor
10 pressure of 16 mm Hg to 22 mm Hg (68°F to 70°F), specific gravity of 1.0 to 2.0, vapor density
11 of from less than 1 to 1, a boiling point of from 212°F to greater than 212°F, and the emulsion is
12 water miscible.

13 In general, Vinyl Acetate Polymers (VAP's) such as the vinyl acetate emulsion used in
14 one embodiment of the composition of the instant invention are hard, brittle, yet tough resins
15 which are found overall to be favorable to the board installation process which requires that the
16 construction board have the ability of being cut and cleanly snapped with a common utility knife
17 after the board has been scored. Additionally, each of the various vendor-supplied VAP's that
18 were tested, when combined in the unique percentages of gypsum and perlite samples tested,
19 were found to be environmentally friendly and not noxious during heat testing. Further, each of
20 the VAP formulations available clearly exhibited the cross linking with starch and mineral
21 (through the use of boric acid), whereby a fusion occurred between the minerals and the adhesive
22 composition. It is thus firmly believed that a chemical fusion of organic and inorganic elements
23 in the composition of the instant invention occurs, rather than a mere adherence by the binder to

1 the mineral. Thus, a fusion occurs which results in a chemically changed binder combination
2 which, when heated, in turn chemically fuses the board formulation.

3 The characteristics of the final vinyl acetate emulsion depend largely on the
4 characteristics of the polyvinyl alcohol used during the manufacture of the emulsion. Wide
5 ranges of polyvinyl alcohols (PVAI's) which can be made are directly dependent upon the
6 characteristics of the intermediate polyvinyl acetate (PVA), especially the PVA's molecular
7 weight and hydrolysis process. PVAI's are generally classified by the percentage of hydrolysis
8 and their degree of polymerization. All polyvinyl alcohols will work in the instant application
9 which are hydrolyzed in preferable ranges from 80 to 100%. Their degree of polymerization
10 based on viscosity at approximately 20°C of 4% aqueous solution, in the range of 5cP (low
11 viscosity) to 60cP (high viscosity) will work in the application. The degree of polymerization of
12 grades which work are in the range of 500 to approximately 2500. The specific PVAI chosen,
13 including the viscosity of the final polyvinyl acetate emulsion, or the derivative of PVAI chosen,
14 shall be field lab or field trial selected. It is primarily dependent on the chemical composition of
15 the gypsum ore, the chemistry of the metered water, and to a significant extent the overall
16 chemical makeup of the constituent additives together. As the temperature increases in the
17 metered water or plant conditions, solubility increases. The fluidity of the wet gypsum slurry
18 finally produced can be directly effected by the proper selection of the PVAI and the final PVA
19 emulsion. Low molecular weight (ca 70-80%) PVAI hydrolyzed grades dissolve rapidly in water
20 at normal room temperatures. It should be noted that solutions of PVAI's in vinyl acetate
21 emulsions mix and disperse more readily in construction board production. They also perform
22 better against "clay shock," as discussed elsewhere in this specification. High molecular weight
23 PVAI's (ca 95-100%) hydrolyzed grades will generally exhibit higher tensile strength. Higher

1 molecular weight PVAI's are dissolved by dispersing in cold water and heating to approximately
2 80-90°C with stirring. Middle range molecular weight (ca 80-95%) grades through hydrolysis
3 are dissolved through slow addition to cold water with stirring, although the temperature can
4 then be raised to 60-80 °C to hasten the process.

5 All VAP's including vinyl acetate homopolymers and copolymers tested were found
6 sufficient to cross-link with starch and boric acid and perform quite satisfactorily in construction
7 board applications. VAP emulsions exhibited preferable mixing ease, dilution and dispersion in
8 the metered process water, and into the final wet gypsum slurry. Homopolymer emulsions were
9 found quite favorable due to their lowest cost, their rapid setting speed, their good ability to
10 adhere to difficult surfaces, and their "dried" strength. Emulsion homopolymers and copolymers,
11 containing polyvinyl alcohol (PVAI) at the right percentages and molecular weight tested (as set
12 forth below), increase the adhesion and cohesion strength, and increase the stabilization (thus the
13 site storage ability) of the final vinyl acetate polymer.

14 Lower molecular weight PVAI's worked better in the presence of sizable clay percentage
15 gypsum ores (i.e., above 1%), to enable initial less thickening of the final wet gypsum with
16 perlite stucco. Higher molecular weight PVAI's increase the absorption of binder molecules
17 onto the particles of the clay minerals or flocculation of clay particles producing in effect "clay
18 shock." The correction for this phenomenon is to utilize lower molecular weight PVAI's that are
19 partially polymerized and hydrolyzed. Thus in essence, they are less "prepared" PVAI's. Partly
20 hydrolyzed grade PVAI's such as GL-02 polyvinyl alcohols of zero to approximately 35 percent
21 to water concentrations should be utilized or added as an anti-shock agent, where there is a fairly
22 sizable presence (i.e., above 1%) of clays in the gypsum, or in the presence of sizable clay
23 percentages (i.e., above 0.1%) in the recycled construction board paper being utilized. The

10% to

0.1% to 30%

a

a

1 partly hydrolyzed grade PVAI's is provided in 25% solution with water, which solution in turn is
2 present at approximately ~~5% to 30%~~ by weight of the binder.

3 The inventor herein has recently discovered a phenomenon that occurs when polyvinyl
4 acetate (PVA) emulsion is added to beta hemi-hydrate gypsum in the practice of the instant
5 invention, and a solution to correct this phenomenon, as follows. When PVA is introduced into
6 the standard construction board manufacturing apparatus, slurry thickening occurs in the pin
7 mixer as the constituents are combined, in turn causing an increase in viscosity which creates an
8 increased water demand to maintain or regain a proper fluidity in the slurry. The increased water
9 demand is a problem in that more energy is required to drive off the excess moisture, and
10 strength is also compromised. The following is an example of post addition of lower molecular
11 weight PVAI to the PVA emulsion before introduction into the pin mixer under conventional
12 construction board line manufacturing production in order to reduce or altogether eliminate the
13 clay shock or thickening phenomenon. A 10% to ^{25%}~~30%~~ solution of PVAI and water (the specific
14 concentration depending upon the severity of the thickening and being easily determined upon
15 inspection during production) is mixed to batch with the PVA emulsion. The ~~ratio of between~~
16 ~~10% to 30% PVAI solution is between 5 and 20 parts PVAI to 80 and 95 parts of~~ PVA emulsion,
17 and can be blended together until a homogenous mix is obtained. The above procedure is
18 practiced prior to the emulsion being utilized in the process of this invention, and the two
19 constituents can be recirculated together to combine once the PVAI is placed into solution. Too
20 much PVAI can affect strength and can cause hydration problems in the system, so the proper
21 ratio is essential. It is particularly of note that due to the siliceous nature of some gypsum
22 deposits, the 10% solution of PVAI may not be sufficient at 5% of the PVA to solve the
23 thickening issue, such that higher concentrations of PVAI would be required to solve the

1 problem. Again, the precise concentration may be easily determined upon inspection during
2 production of the construction board of the instant invention. In addition, a small amount of
3 Sorbitol (between 0.1% and 5%) in approximately 70% solution can act as a vehicle for the
4 gypsum to attach to instead of attaching to the polyvinyl alcohol contained within the PVA
5 emulsion itself. This is the purpose of post adding the lower molecular weight PVAI to the PVA
6 emulsion, namely, to counteract the reaction causing the thickening allowing more PVAI to react
7 with the gypsum. It is believed that the chemical reaction that occurs when PVA is added to the
8 stucco can be countered with the post addition of the lower molecular weight PVAI. While it
9 would be most preferable to blend the PVA with the lower molecular weight PVAI at the
10 emulsion manufacturing site so as to be ready to use when received at the construction board
11 manufacturing facilities, the current need of evaluating the thickness of the slurry during board
12 production to establish the appropriate concentration requires that the two constituents be
13 combined at the board manufacturing facility.

14 Thickening of the final gypsum/perlite slurry can also be corrected or further corrected
15 through other methods. One simple solution is to utilize oxidized starch in the presence of
16 PVAI's or PVA's. Further improvements in fluidity will occur when waxy oxidized starch is
17 used. The type of starch used, or preferred, is discussed in other parts of this specification.
18 Higher-grade starches will produce better reactions and strength results, and should be weighed
19 in terms of total cost in determining the final selected and prepared PVAI and PVA copolymer or
20 homopolymer emulsion utilized.

21 It was also found favorable to raise the glass transition temperature (T_g) of the polymer
22 system for better fire testing results of the samples tested. A higher fire rating using VAP's
23 would certainly be preferred in construction board applications. The T_g range from 28°C to

1 39°C, with higher T_g being preferred in VAP applications, were examined during fire tests, and
2 yet all were found acceptable. In order to obtain higher transition temperatures (T_g), other
3 copolymers may be prepared and/or pre-added to the emulsion in smaller quantities, such as 2-
4 ethyl hexylacrylate, ethyl acrylate, dibutyl fumarate, vinyl stearate, polymethyl methacrylate, or
5 butyl methacrylate. Cost should be considered in percentages used as these will generally
6 increase the overall modified polymer emulsion cost.

7 As mentioned above, it is a significant feature of the instant invention that the
8 manufacture of the synthetic adhesive binder incorporated into the Examples provided below is
9 carried out at the construction board production facility, as opposed to being manufactured
10 offsite and later transported to the construction board production facility. More particularly, for
11 the examples provided below, the base components of the binder are acetic acid and ethylene
12 which make up a vinyl acetate monomer, which in turn is polymerized into a vinyl acetate latex
13 emulsion. The process by which this occurs and the equipment needed to accomplish the
14 polymerization of the above-listed constituents is located at the site of the construction board
15 manufacturing facility to significantly reduce costs.

16 The manufacture of the polyvinyl acetate emulsion containing polyvinyl alcohol at the
17 construction board manufacturing facility provides many distinct advantages. The cost of the
18 emulsion is reduced in the weight and transportation cost of the main individual components.
19 PVA emulsions have been made for other applications, but have not previously been used in
20 construction board manufacturing. Accelerators, strengthening agents, percentages of PVA and
21 PVAI's, proper end foam generation controls, additives, and stabilization requirements can be
22 uniquely controlled for optimization in construction board usage. Also, another important factor
23 is reduced cost requirements to stabilize and protect from bacteria the final transported PVA

1 emulsion, because the PVA emulsion created is continuously used in the manufacture of the
2 construction board. Also, a consistent quality controlled source of supply is always readily
3 available. Climate conditions (such as winter freeze problems that adversely affect PVA
4 performance), potential contamination of the product in multiple handling, premature agitation
5 which can effect strength performance, and storage buildup of the dried emulsion can be reduced
6 and therefore lower the overall cost of the PVA emulsion.

7 Further, newer improved manufacturing techniques to make PVA emulsions can be
8 employed and master linked computer controlled to optimize production quality and capacities
9 immediately required for the changes in the board formulations of the various sized and types of
10 construction board products.

11 The making of vinyl acetate (VA), vinyl acetate polymers (VAP's), and vinyl acetate
12 monomers (VAM's) onsite at the board manufacturing facility further lowers the cost at the
13 volume usage demanded for construction board applications. VAM's and the elements that
14 make up VAM's, which are key base compounds of VAP's, are determinative factors in the
15 ultimate cost of the board manufacturing process. Thus, using the processes and placing the
16 equipment designed to manufacture VAP's at the construction board manufacturing facility plays
17 a substantial role in lowering the ultimate production cost of VAP's.

18 Still further, the stability of a colloidal suspension of vinyl acetate in emulsion is
19 determined by the length and time the emulsion must sit or be unutilized. The longer the
20 emulsion must be "stabilized," the higher the cost of the emulsion. Therefore, lower costs are
21 realized through the continuous use of the emulsion promptly after it is prepared, as in the
22 continuous construction board manufacturing application of the instant invention where the
23 adhesive is manufactured on-site.

1 The manufacture of the final synthetic binder at the production site exhibits significant
2 reduction in production costs. Traditionally, synthetic construction board energy costs are
3 significantly reduced through the industry practice of contracting with power plants to dispose of
4 some of the waste produced by the power plant by using it as a constituent of the synthetic board,
5 in exchange for reduced costs in the supply of electricity. Therefore, the energy costs associated
6 with the manufacture of the adhesives at the site of the construction board manufacturing facility
7 are significantly reduced. Moreover, the presence of manufacturing labor at the construction
8 board manufacturing facility, which labor can likewise manufacture the adhesives, reduces the
9 total number of employees required to manufacture the adhesives, once again reducing the
10 overall manufacturing costs. The additional development or polymerization of other adhesives
11 manufactured on site will additionally reduce production costs. The labor and energy required to
12 transport the amount of adhesive material needed to manufacture mass quantities of construction
13 board from a location other than the site on which the board is manufactured would not be
14 logistically or financially feasible in a large production setting.

15 It has been discovered by the inventor herein that the selected binder can be caused to
16 foam when mixed vigorously enough with processed water. The foamed binder can aid in
17 aerating the board and decrease or even eliminate the need for soap foaming agents currently
18 used to aerate construction board in manufacturing. This in turn reduces the cost of the board
19 manufacturing process by reducing the need for soap foaming agents. It is believed that soap
20 bubbles and soaps in general do nothing for and actually tend to diminish the strength of the
21 ground gypsum, perlite particles and/or other dry constituents from bonding or cohering to each
22 other and then to the board paper plies. Soaps used today do not aid in sticking or gluing
23 particulates together but separate or repel them from doing the same. Therefore, the binder need

be of proper combination and viscosity to form the proper sized bubbles and remain reasonably constant through the kiln drying process to properly aerate the finished board. Polyvinyl acetate emulsions when mixed properly with water, similar to soaps, will foam and can produce a stronger same size bubble due to their surfactant content.

The binder or emulsion can also be slightly altered in viscosity by adding other binders or foaming agents to enhance proper sized bubbles that react similarly, yet firmer, than soap bubbles. Examples of nonionic surfactants which can be useful in this invention are polyethers, e. g., ethylene oxide and propylene oxide condensates which include straight and branched chain alkyl and alkaryl polyethylene glycol and polypropylene glycol ethers and thioethers; alkylphenoxypoly (ethyleneoxy) ethanols having alkyl groups containing from about 7 to about 18 carbon atoms and having from about 4 to about 240 ethyleneoxy units, such as heptylphenoxy-poly (ethyleneoxy) ethanols, octyl-and nonylphenoxy-poly (ethyleneoxy) ethanols; the polyoxy-alkylene derivatives of hexitol (including sorbitans, sorbides, manitans and mannides); partial long chain fatty acid esters, such as the polyoxyalkylene derivatives of sorbitan monolaurate, sorbitan monopalmitate, sorbitan monostearate, sorbitan tristearate, sorbitan monooleate and sorbitan trioleate; the condensates of ethylene oxide with a hydrophobic base, said base being those formed by condensing propylene oxide with propylene glycol; sulfur containing condensates, e. g., those prepared by condensing ethylene oxide with higher alkyl mercaptans, such as nonyl, dodecyl, or tetradecyl mercaptan, or with alkylthiophenols wherein the alkyl group contains from about 6 to about 16 carbon atoms; ethylene oxide derivative of long chain carboxylic acids, such as lauric palmitic, oroleic acids or mixtures of acids, such as tall or fatty acids; and ethylene oxide derivatives of long chain alcohols such as octyl, decyl, lauryl, of cetyl alcohols.

1 The preferred nonionic surfactants useful to be added to the latex polymer for the purpose
2 of dispersing the latex polymer throughout the gypsum slurry and creating a stronger bubble than
3 can be achieved with the more commonly used wallboard foaming agents are higher (greater
4 than C8) aliphatic alcohol alkoxylates, aliphatic acid alkoxylates, higher aromatic alcohol
5 alkoxylates, fatty acid amides of alkanolamines, fatty acid amide alkoxylates, propylene glycol
6 alkoxylates, block or random copolymers of ethylene and propylene oxide, higher (greater than
7 C8) alcohol polyethylene polypropylene block or random adducts and mixtures thereof. Of the
8 above classes of nonionic surfactants, the alcohol ethoxylates and alkaryl ethoxylates are
9 particularly preferred. In practice, the ~~amount of~~ nonionic surfactant to be added to the latex
10 polymer is about 1 to about 30 parts per 100 parts of polymer.

11 Additionally, the binder or emulsion can be pre-mixed with the starch in solution to
12 further enhance or control the foaming presence. The most important difference however from
13 just using soap foam water is that the final combined binder solution bubbles will grab onto and
14 adhere to the gypsum, perlite or expanded mineral, and other dry ingredients in the pin mixer and
15 then grab onto the board paper to form more bonded, firm, and therefore stronger composite
16 construction board.

17 Additionally, water based non-V.O.C. acrylic or polyurethane polymer systems can be
18 utilized as the binder in the formulation of the construction board of the present invention either
19 alone or in combination with other polymer systems mentioned herein. The benefit of using a
20 water based non-V.O.C. polymer system in formulating the composite core from an
21 environmental standpoint is a polymer that is completely non-toxic to the workers who work
22 with it as well as having no detrimental effects on the ecosystem surrounding the manufacturing
23 plant where it is being utilized. Being water-based, the system is very compatible with the other

1 constituents that make up the core of the gypsum construction board of the instant invention. The
2 non-V.O.C. polymer system is completely biodegradable and safe to the environment as opposed
3 to petrochemical polymers and worked as well as or better than many of the petrochemical based
4 polymers tested.

5 A compatible fire retardant, such as boric acid, zinc borate, sulfamates, diammonium
6 phosphate, nitrogen compounds, antimony oxide, silica, titanium oxide, zircon and others can be
7 used and comprise from about .15 percent to about 3 percent by weight of the board. These fire
8 retardants can be added to the formulation by powder or solution during the slurry mixing
9 process, and also by spraying onto the paper covering for the purpose of fire retarding the
10 laminate covering paper of the construction board. The examples of applying fire retardants are
11 listed as follows:

12 Example 1 (Fire retardant, moisture resistant system): this system sprays fire retardant
13 solutions directly onto the board as it leaves the cascade sections and enters the take off area of
14 the manufacturing equipment. This is accomplished by using spray heads overhead together
15 with switch activators to trigger the action as the board passes by on the conveyor. Additives are
16 supplied by storage tanks and pressure type discharge systems. The additives are sprayed
17 directly on the face paper.

18 Example 2 (Fire Retardant): another way to apply a fire retardant quality to the paper is to
19 add it in dry form during the Krafting process of the paper's manufacture. Small particle
20 distribution of fire retardant are added to the pulp slurry prior to extrusion into the paperboard.
21 This allows for the fire retardant to be completely integrated into the paper. This fire retardant
22 could be zinc borate, antimony oxide, nitrogen compounds or sulfamates (sulfur compounds).
23 These are all common fire retardants in paper.

1 Fire Retardant additives to the adhesives, such as the addition of boric acid, reduce the
2 overall flash point of these chemicals and therefore increase the fire rating of the core composite.
3 Under fire rating test samples, the presence of noxious fumes were greatly reduced even to the
4 point of being virtually eliminated as the samples moved away from the epoxies and non-water
5 solvent adhesive mixtures. The combination of vinyl acetates with cementious materials also
6 provided a good fire retardant combination without the addition of boric acid.

7 Optionally, an improved construction board cover material consists of a manila colored
8 moisture resistant paper face sheet in the range of 40-50 pounds with an altered top ply. In
9 traditional construction board structures incorporating a cover material composed of recycled
10 paper pulp, the length of fibers in the cover material is between 1/2 and 3/4 inches. The instant
11 invention, however, employs a top ply sheet composed of virgin fibers of 1 inch or greater.
12 While papers incorporating fiber lengths of greater than 1 inch have been produced in the past, to
13 the best of the inventor's knowledge, no such virgin pulp has been applied previously to the top
14 ply cover sheet of a construction board sheet. Thus, the inclusion of such extended length fibers
15 into the construction board cover sheet of the instant invention provides the unforeseen and
16 unobvious benefit of providing a much stronger break strength than previously known
17 construction board structures.

18 The unique application of the optional spec paper cover sheets of the construction board
19 of the present invention is completely formed by any well known paper forming process. Using
20 100 percent "virgin stocks" for the top ply of the face paper cover sheet allows for predictable
21 liner strength while also eliminating some of the clays and fillers associated with current
22 completely recycled construction board paper. By integrating a virgin pulp top ply with existing
23 recycled construction board paper plies, increased strength and wet handling characteristics are

1 achieved. First, a paper cover sheet is made generally comprising a multiply sheet
2 manufactured on a cylinder machine. Conventional sizing compounds are added to selected vats
3 such as rosin and alum to internally size some or all plies. The plies are removed and laminated
4 to form an essentially unitary web of paper. After being dried, the paper is coated with a water
5 emulsion of the synthetic size of the class consisting of certain substituted succinic acid
6 anhydrides, certain substituted glutaric acid anhydrides and the reaction product of maleic acid
7 anhydrides with an internal olefin. This process allows for effective absorption into the bond
8 liner of the core side of the paper to provide a mechanical linking of the paper to the composite
9 core.

10 Alternately, a cover sheet may be utilized comprising a combination of non-wood type or
11 organic fibers such as Kenaf with or without recycled waste paper wood pulp fibers. Utilizing a
12 completely or partially tree-free pulp creates a construction board having a more environmentally
13 friendly cover sheet than traditional construction board products. Typically, recycled wood pulp
14 fibers are shorter in length, by up to half, over their virgin pulp counterparts, and the strength that
15 papers manufactured with virgin pulp fibers achieve cannot be duplicated with recycled fibers.
16 However, papers manufactured with virgin wood pulp fibers are much more costly when
17 compared to the cost of papers manufactured with the recycled wood waste pulp variety. By
18 integrating stronger non-wood type organic fibers into the recycled wood waste pulp during the
19 paper manufacturing process, a much thinner but stronger paper cover sheet is realized, allowing
20 the construction board of the instant invention to more easily meet ASTM and Building Code
21 requirements when very lightweight core formulations are being utilized. The weight percentage
22 of fiber of a source other than wood can vary from 1 to 100 percent of the pulp formulation
23 depending upon the desired end result.

As yet another alternative, the paper cover sheets of the construction board of the instant invention may be reinforced using fiberglass mesh material integrated between the inner face liner of the paper cover sheet and the remaining laminates to produce highly abuse-resistant lightweight construction boards. When utilizing formulations to produce construction boards with densities at under 30 pcf (pounds per cubic foot), flexural strength can be reduced significantly in the core. By integrating a fiberglass mesh material beneath the inner surface laminate of the paper facer, flexural or paper grain strength can be retained well above ASTM utilizing slurry formulations to produce abuse-resistant construction boards of the instant invention as low as 25 pcf density. As paper is the majority of the strength of gypsum construction board, this fiberglass mesh material also strengthens sheer panel strength of the invention when utilizing lightweight construction board core formulations of the instant invention. The paper facers utilized in the production of gypsum construction board are normally made on cylinder machines from recycled paper in order to produce a porous paper capable of receiving the gypsum crystals that grow from the wet core slurry prior to drying. The placement or integration of the fibers between the inner liner face of the cover sheet and the remaining laminate layers can be achieved during the paper manufacturing process after the paper is formed into a fibrous web from the pulping process. The introduction of a non-woven fiber mesh into the papermaking process is achieved through placement of the mesh between the fibrous sheets during the laminating process, before dewatering. The same sizing compounds can be utilized and the porous properties of the paper remain the same. The fiberglass material or mesh can be oriented in a variety of crisscross patterns or evenly spaced shapes. Optionally, the mesh can be interlinked similar to a chain link fence within the inner laminate of the facer sheet to further increase its strength. The paper facers will still maintain their ability to absorb

1 the slurry and the properties of the fiberglass will be such that the gypsum crystal can also
2 mechanically link to the fiberglass strands as well. The fiberglass strands can be of various
3 lengths, with the preferred length being 2 inches or greater. The fibers will increase the flexural
4 and racking loads that the wallboard will be able to withstand both during construction and also
5 once the structure is completed. The fiber integration will greatly increase the abuse resistance
6 of the construction board while maintaining lighter weights when compared to abuse resistant
7 boards currently on the market.

8 Even further, the inner liner of the facer sheets can be subjected to an abrasive during the
9 manufacturing process to provide a rough finish, to in turn allow for an improved bonding
10 between the stratum of the gypsum core and the facer sheets. The roughed up liner surface of the
11 facer sheets causes an improved surface for the gypsum slurry crystal growth to adhere with in
12 contrast to the very smooth surfaces found on gypsum wallboard paper facers commonly
13 utilized.

14 If bituminous or waxy water-repellent materials are used, they comprise from about 1.0
15 percent to about 10 percent of the Perlite weight by volume. These materials may be applied to
16 the Perlite from molten states or as emulsions. If silicone emulsions are used, the silicone
17 comprises from about 0.01 to about 2 percent of the Perlite by weight. The silicone emulsions
18 may be applied directly to the Perlite as it exits the expander by means well known in the art.

19 20 Apparatus

21 The apparatus necessary for implementing the above-described method comprises several
22 elements which together take expanded Perlite and combine it with varying reactants, apply the
23 mixture to a paper substrate to form a continuous sheet of laminated Perlite wallboard, convey

the wet Perlite wallboard along a conveyor while subjecting it to an initial heat treatment as the wet board travels towards a rotary cutting knife, transferring the laminated assembly to a board dryer, and finally processing the dried wallboard for shipment.

As shown more particularly in the schematic Perlite processing arrangement of Figure 1, a Perlite expander system is provided of conventional design. A preferred Perlite expander is readily commercially available from Silbrico Corporation as model number M-30, although any similarly configured Perlite expander would likewise be sufficient. The Perlite expander system comprises a covered hopper car 1 which delivers Perlite ore that has been crushed to the sieve size enumerated above to a conveyor 2 positioned beneath the hopper car 1. Conveyor 2 delivers the Perlite ore to an elevator 3 which, in turn, transfers the Perlite to an ore storage container 4. When the crushed Perlite is to be processed into expanded Perlite, a reclaim conveyor 5 is used to deliver the crushed Perlite to a Perlite ore surge bin 6, which in turn directs the crushed Perlite ore to an ore feeder 7. Ore feeder 7 directs the crushed Perlite ore via a downwardly oriented elongate chute to a four-way Perlite ore splitter 8. At ore splitter 8, the Perlite ore travels further downward through four elongate tubular passages and into the vertical furnace expanding tube of Perlite expander 9. As the crushed Perlite is introduced into the vertical furnace expanding tube of Perlite expander 9, the crushed Perlite is met by compressed air which is heated between 1000 and 2100 degrees Fahrenheit. This heating process causes the crushed Perlite material to soften while the water bound to the Perlite particles rapidly evaporates, in turn expanding the Perlite ore to between 12 to 20 times its original size and into a light, cellular particle which is commonly referred to as "expanded Perlite." Once the Perlite has been expanded, the expanded Perlite particles are light enough to travel upward in the air stream within the vertical furnace expanding tube, through a duct 10 at the top portion of the expanding tube, and into a cyclone collector 11.

1 Within cyclone collector 11, the larger expanded Perlite particles fall downward and settle into a
2 hopper at the lower end of the cyclone collector, while the smaller, fine expanded Perlite
3 particles travel upward from the cyclone collector through a duct and into a dust collector 12
4 where they settle. Within dust collector 12, the extremely fine particles (which are generally not
5 useable in the wallboard production process) are collected by a fiber filter media within dust
6 collector 12. The remaining fine particles and the larger expanded Perlite particles from the
7 hopper of cyclone collector 11 are directed to an expanded Perlite storage silo 200, as described
8 in greater detail below.

9 In a preferred embodiment of the present invention, two independent Perlite expansion
10 systems are utilized in order to provide an appropriate supply quantity of expanded Perlite to the
11 wallboard production apparatus.

12 As shown in the schematic diagram of the Perlite wallboard production facility of Figure
13 2, located at the feed end of each Perlite expansion system 100 is a dense phase pneumatic
14 transport system 400 which moves the expanded Perlite from the Perlite expansion system 100 to
15 a plurality of storage silos 200. A suitable dense phase pneumatic transport system is readily
16 commercially available from Nol-Tec Systems, Inc. of Lino Lakes, Minnesota as Transporter
17 model number 201, although any similarly configured pneumatic transport system would
18 likewise be sufficient. The pneumatic transport system is configured to pneumatically convey
19 expanded Perlite from the Perlite expansion system 100 to the expanded Perlite storage silo 200,
20 and in turn from the storage silos to a secondary feed tank 300 located within the wallboard
21 manufacturing facility. The dense phase pneumatic transport system has the ability to fluidize
22 the dry expanded Perlite material using air pressure, and in turn to convey the material to the
23 desired location using sealed pressurized tubes. The transport system utilizes relatively high

1 pressure (above 15 psig), low volume air as the force to transfer the granular bulk solids through
2 a pipeline at low velocity, creating dense packets or slugs of expanded Perlite which travels
3 through the conveyor system without risk of the abrasive expanded Perlite material damaging the
4 interior of the conveyor pipeline.

5 It should be noted that alternate means of conveying the expanded Perlite are available,
6 such as the utilization of a screw type conveyor or similarly configured mechanical conveyance
7 apparatus. However, it has been found that such mechanical conveyance means used in the
8 transport of expanded Perlite in the context of wallboard manufacture incurs a substantially
9 higher equipment and maintenance cost. Thus, the use of a dense phase pneumatic transport
10 system for conveyance of expanded Perlite during the wallboard manufacturing process provides
11 a substantial improvement over traditional bulk material transport means previously used in the
12 wallboard manufacturing process.

13 As mentioned above, the dense phase pneumatic transport system 400 is used to transfer
14 expanded Perlite from the Perlite expansion system 100 to a plurality of storage silos 200 of
15 conventional design for storing the expanded Perlite until needed for new wallboard production.
16 Each storage silo is equipped with an airslide of conventional design and known to persons of
17 ordinary skill in the art of dry bulk material handling. The airslide directs expanded Perlite from
18 each of the storage silos to a transition hopper positioned above a second dense phase pneumatic
19 transport system.

20 The second dense phase pneumatic transport system is used to convey expanded Perlite
21 from the storage silos 200 to a secondary feed tank 300 inside of the wallboard manufacturing
22 facility. This second dense phase pneumatic transport system is configured nearly identical to
23 the first dense phase pneumatic transport system, the sole variations in the system relating to the

1 conveyance capacity of the respective systems as determined by the wallboard production goals
2 of the particular manufacturing facility. It should be apparent to those of ordinary skill in the art
3 that modifications could readily be made to the precise handling capacity of each of the
4 pneumatic transport systems in order to meet the production requirements of the particular
5 facility, such as by modifying the diameters of the pipelines in the conveyor system or by
6 modifying the pressure within the pipeline to in turn change the velocity of the materials being
7 transferred within.

8 Traditional wallboard production facilities are plagued with the problem of significant
9 production down-time whenever a problem with the raw material processing and storage
10 equipment located upstream of the actual wallboard construction equipment is experienced.
11 Such problems can include air pockets or channels within the storage silos which inhibit or
12 prevent the free flow of material, clogged processing lines, and other common material handling
13 problems. In order to prevent the costly losses that such down time would create, the present
14 invention employs a secondary expanded Perlite feed tank 300 comprising a steel tank positioned
15 within the wallboard manufacturing facility in general proximity to the wallboard construction
16 equipment.

17 It is significant that traditional gypsum wallboard production facilities have been unable
18 to dispense gypsum from a single feeder container, but instead have been required to direct
19 processed, calcined gypsum to multiple small storage bins of limited supply capacity such that
20 the entire supply in each bin would be consumed by the production process in a single day. The
21 reason for using such an expensive and inconvenient supply system requiring constant
22 replenishment relies on the fact that calcined gypsum plaster cannot be stored in large quantities
23 as it has a tendency to absorb surrounding moisture, in turn causing premature hardening. Thus,

1 the present improved wallboard construction process enables a simplified expanded Perlite
2 supply tank to be utilized as the expanded Perlite lacks the moisture sensitivity and long term
3 storage sensitivity of calcined gypsum.

4 As the Perlite expanders work to fill the storage silo that is least full with expanded
5 Perlite, expanded Perlite from the most full storage silo is drawn out and directed to the
6 secondary feed tank 300, using a programmable logic controller as is well known to those of
7 ordinary skill in the art. By constantly maintaining at least one full silo and by always keeping
8 the secondary feed tank filled with expanded Perlite, the risk of being forced to shut down the
9 wallboard production line due to the above-mentioned equipment problems is at least reduced, if
10 not eliminated altogether. The maintenance of a separate, secondary expanded Perlite feeder
11 tank that is constantly maintained with a ready supply of expanded Perlite, and positioned
12 adjacent the wallboard production equipment, enables any such equipment malfunctions in the
13 remaining storage and pre-processing equipment to be resolved before the supply of expanded
14 Perlite has diminished to such a level that it can no longer supply the expanded Perlite to the
15 production equipment. Likewise, in the event that each element in the pre-processing and
16 expanded Perlite storage equipment fails, the supply within the secondary feeder tank may be
17 used to supply the expanded Perlite to the production equipment until such supply is fully
18 consumed or the failure in the pre-processing and storage equipment is resolved.

19 The secondary expanded Perlite feeder tank supplies expanded Perlite to the wallboard
20 fabrication equipment using volumetric feeders to feed the dry ingredients into a continuous
21 auger type blender 550. A suitable volumetric feeder is readily commercially available from
22 Acrison as Model BDF. It is of note, however, that alternate means may likewise be provided
23 for directing the dry Perlite to the wallboard fabrication equipment, including the above-

described commercially available dense phase pneumatic transport system. Further, a suitable auger type blender is readily commercially available from Acrison as Model Number 350, although any similarly configured blender will likewise suffice. Blender 550 in turn conveys the dry components of the wallboard composition to a pin mixer 600.

As explained in greater detail below, the liquid constituents 700 of the adhesives are added into the metered water, or other mixing soap or starch waters, and diluted before being added into the pin mixer 600 along with water and a foaming agent for combining with the dry components of the Perlite wallboard.

Continuous pin mixer 600 is of a conventional design, and a suitable continuous pin mixer is readily commercially available from Asa Brown Bovari ("ABB") Raymond Ehram Operations, although any similarly configured pin mixer would suffice. The continuous pin mixer combines the dry components of the Perlite wallboard construction with the foamed adhesives, all of which are metered into mixer 600 at a uniform rate. The resulting homogeneous wet gypsum/perlite slurry free flowing is then discharged from the continuous pin mixer through a rubber-like flat opened end boot or hose 650 (which is normally approximately 6-10 inches wide by 1/2 to 1 1/2 inch rectangular opening or approximately 2 1/2 to 4 inch diameter hose or hoses). It is preferable to comprise the exit boot or hose(s) of proper latex rubber to handle the larger and coarser Perlite when used and to widen the width of the boot or hose to compensate and more widely spread out the slurry or mixture onto the back side of the face paper. The reason is that the Perlite or expanded mineral is lighter and of lesser density and different viscosity due to the binder than the normal wet gypsum slurry, and therefore behaves slightly different in spreading uniformly and evenly onto the back side of the face paper. The face paper

1 is delivered to the wallboard assembly line from paper handling equipment 800 positioned
2 upstream of the pin mixer.

3 The paper handling equipment 800 is likewise of conventional design, and a suitable
4 paper handling equipment arrangement is readily commercially available from ABB Raymond
5 Ehram Operations, although any similarly configured paper handling equipment system would
6 suffice. The paper handling equipment arrangement provides the backing and face paper to the
7 wallboard production line, and generally includes paper roll racks or rotary unwind stands that
8 hold the paper, paper pull rolls that supply the paper at a constant speed to paper tensioners
9 which in turn automatically adjust to apply uniform tension to the paper, paper splicing tables
10 where the end of the paper from a new roll is joined to the end of a spent roll, paper guides that
11 automatically align two streams of paper with the boardline and ensure even paper flow
12 downstream, paper heaters to remove any moisture from the paper, and paper creasers to prepare
13 the paper so it folds precisely further downstream.

14 Wallboard forming apparatus 810 comprising an adjustable mud dam/edger and an
15 extruder-type forming plate or forming rolls all of conventional design are located just
16 downstream of the pin mixer. The adjustable mud dam/edger folds the already creased face
17 paper being supplied from the paper handling equipment into position to receive the glued
18 backing paper, while establishing the board width and edge configuration. The extruder-type
19 forming plate or rolls determine the thickness of the wallboard as it enters the conveyor line, and
20 brings the backing paper into contact with the mixture and gluing it to the folded face paper to
21 create the enclosed envelope that holds the free flowing mixture in the shape of a continuous
22 board.

1 After the free flowing mixture has been applied to the paper, a continuous, wet wallboard
2 sheet is formed which proceeds along a board forming line conveyor of conventional design
3 comprising a greenboard forming line section and a live roll section. The greenboard forming
4 line section (shown generally at 900) comprises a flat belt surface with very closely spaced rolls
5 to provide adequate belt support to maintain a flat board structure as the wet board travels along
6 the board forming line, and generally extends approximately two-thirds of the distance between
7 the forming plate or rolls and a cut-off knife 910. The live roll section (shown generally at 950)
8 extends the remaining one-third of the distance, and serves to deliver partially set board to the
9 cut-off knife. The live roll section 950 comprises open rolls which allow exposure of the board
10 face to the air and help the final greenboard set prior to cutting. An aligning device of
11 conventional design is also positioned ahead of the knife which positions the board to assure a
12 square cut.

13 It is important in the wallboard manufacturing process to ensure that the greenboard is
14 sufficiently set by the time it reaches the cutting knife so that the knife is able to make a clean cut
15 through the wallboard without picking up excessive wet substrate material from the board which
16 in turn could gum up the knife surface. In the examples set forth below in which gypsum is not
17 used as a setting or hardening agent in the composition, in order to ensure that the Perlite
18 wallboard of the present invention has reached a sufficiently dry state to prevent the substrate
19 from collecting on the knife surface, the Perlite wallboard forming line is preferably provided
20 with an optional initial heat treatment means which directs heat towards the wet wallboard as it
21 travels from the forming plate or rolls to the cut-off knife. However, another substantial benefit
22 arises from the heat treatment of the wet board prior to cutting, and that is the significant cost

1 reduction realized by the reduction in processing times and temperatures required to fully set the
2 board within the drying kiln, as explained in greater detail below.

3 In a first embodiment of the heat treatment means, a tunnel 920 is provided which
4 encapsulates the board line between the forming plate or rolls and the cut-off knife. The tunnel
5 is provided with a series of interconnected air ducts 921 along its upper interior surface, air ducts
6 921 being configured to direct hot air directly downward on the wet board as it travels along the
7 board line. Heat is supplied to the tunnel using any conventional and readily commercially
8 available air duct system which directs heat from the hot air recycling system of the drying kiln
9 1200 (discussed in greater detail below) to the duct work located at the ceiling of the heating
10 tunnel. Fans are suspended from the ceiling of the heating tunnel to direct the heated air from
11 the downwardly directed air ducts to the board line.

12 In a second embodiment of the heat treatment means, a series of drying hoods are
13 positioned over the board line. The hoods are of conventional design for a standard ventilation
14 hood, and generally comprise a wide, open-mouth air duct opening which faces the surface to be
15 heated (i.e., the board line), and a section of duct work which extends upward from the wide,
16 open-mouth air duct opening and which narrows as it rises away from the air duct opening until
17 it reaches the diameter of the remainder of the duct work. Fans are positioned within the air duct
18 to direct the heated air into the ducts and out of the hoods towards the board line. As in the first
19 embodiment, heat is supplied to the individual drying hoods using any conventional and readily
20 commercially available air duct system which directs heat from the hot air recycling system of
21 the drying kiln (discussed in greater detail below) to the drying hoods.

22 After the board has traveled along the belt forming and live roll dewatering sections, the
23 continuous wallboard is cut into individual sheets using a rotary cut-off knife 910 of

1 conventional design. A suitable rotary cut-off knife is readily commercially available from ABB
2 Raymond Ehram Operations of Abilene, Kansas, although any similarly configured cut-off
3 knife would likewise suffice. The cutting is performed by two knife blades, each mounted on a
4 rotor, one above and one below the board. When cutting, the rotors run slightly faster than the
5 speed of the board line to assure that the knife blades make a straight cut.

6 Following the cutting of the board by the rotary cut-off knife, the individual wallboard
7 sheets are directed along a board accelerator section (shown generally at 960) of conventional
8 design. A suitable board accelerator section is readily commercially available from ABB
9 Raymond Ehram operations of Abilene, Kansas, although any similarly configured accelerating
10 conveyor section would likewise suffice. The board accelerator section comprises sets of rolls
11 turning at increasing speeds to accelerate the cut boards beyond the cut-off knife in order to
12 provide adequate spacing between boards to allow time for transfer and inversion of the boards
13 to the dryer infeed section of the boardline. At the end of the accelerator section, the boards are
14 received by a board transfer/inverter assembly 1000 of conventional design. A suitable board
15 transfer/ inverter assembly is readily commercially available from ABB Raymond Ehram
16 operations of Abilene, Kansas, although, once again, any similarly configured panel
17 transfer/inverter assembly would suffice. The transfer/inverter moves the boards laterally at 90
18 degrees to the boardline while turning the boards face side up and aligning them side by side
19 before they are introduced into the drying kiln.

20 Once the boards have been inverted and transferred to the dryer infeed section of the
21 boardline, a dryer infeed assembly (shown generally at 1100) comprising a conveyor directs
22 boards from the board transfer/inverter assembly to the multideck infeed section of the drying
23 kiln. A suitable dryer infeed assembly is readily commercially available from ABB Fläkt

1 Industri Ab of Växjö, Sweden, although any similarly configured conveyor-type feeder system
2 would suffice.

3 Drying kiln 1200 of the present invention comprises a plurality of tiers, preferably
4 between 12 and 15, of roller conveyors which receive wallboard at the inlet end of the kiln,
5 convey the wallboard through the multiple heating zone drying section, and discharge the
6 wallboard at the outlet end of the kiln. The basic configuration of the drying kiln is of
7 conventional design and well known to those of ordinary skill in the art, and a suitable board
8 drier kiln is readily commercially available from ABB Fläkt Industri Ab of Växjö, Sweden. The
9 preferred drying kiln of the present invention comprises a two heating zone kiln of conventional
10 design. It is significant, however, that the use of Perlite as the primary constituent of the
11 wallboard of the present invention and the process of providing an initial heat treatment of the
12 wet board prior to cutting allows the drying process to be carried out at significantly lower
13 operational temperatures within the drying kiln. These lower operational temperatures provide a
14 significant cost savings in both energy consumed in the drying process and in premature wear in
15 the components of the dryer itself caused by long term exposure to extreme operating
16 temperatures.

17 As mentioned above, the heat supplied to the optional heat treatment assembly over the
18 wet board line is supplied by tapping the hot air recycling system of the drying kiln. As shown
19 in Figure 2, in a conventional wallboard drying kiln configuration, stacks 1210 which comprise a
20 flue or exhaust pipe extending upward from the kiln and through the roof of the manufacturing
21 facility are located at each end of the drying kiln to enable moisture laden hot air to escape from
22 the interior of the kiln. The release of this moisture aids in the evaporation process to drive off
23 the excess water that is present in the wallboard product. As the air rises in the stack, a portion

1 of the air is captured through side ducts located in the sidewalls of the stacks. The side ducts are
2 provided with fans which direct at least a portion of the rising air into the ducts which in turn
3 direct the captured air to a condenser. The condenser recaptures the moisture from the air, and
4 the now dry air is returned into the air inlet 1220 of the drying kiln. Such a hot air recycling
5 system is well known to those of ordinary skill. The present invention redirects the heated dry
6 air exiting the condenser through duct work of conventional design to the optional heat treatment
7 apparatus situated above the board line, as explained in depth above.

8 Following the drying stage, the fully set Perlite wallboard exits the drying kiln via a dryer
9 outfeed system 1300 of conventional design. A suitable dryer outfeed system is readily
10 commercially available from ABB Fläkt Industri AB of Växjö, Sweden, although any similarly
11 configured conveyor-type outfeed system would suffice. The dryer outfeed system in turn
12 directs the Perlite wallboard to dry wallboard handling apparatus, including a transfer-booker
13 1400, a board bundler 1500, and a board stacker 1600.

14 A suitable transfer-booker 1400 of conventional design is readily commercially available
15 from ABB Raymond Ehram Operations of Abilene, Kansas, and is used to move each pair of
16 boards off of the dry end boardline onto a receiving table supported by a plurality of rolls, which
17 rolls drop away to allow a series of belts to rotate the board by 90 degrees. Hydraulically
18 actuated arms then lift opposing ends of each pair of boards such that the boards are brought
19 together face to face to protect the smooth outer surfaces of the wallboard from damage during
20 handling, storage, and shipping.

21 The paired or "booked" boards are then directed to a board bundler 1500 of conventional
22 design which squares and aligns the pair of boards, trims them to precise finished length, and

1 tapes the ends. A suitable board bundler of conventional design is readily commercially
2 available from ABB Raymond Ehram Operations of Abilene, Kansas.

3 Finally, after the wallboards have been bundled, they are transferred via a board stacker
4 assembly of conventional design to a mechanism which automatically aligns the bundles and
5 places them one upon another such that the bundles may be lifted and carried by a forklift to a
6 storage location. A suitable board stacker assembly of conventional design is readily
7 commercially available from ABB Raymond Ehram Operations of Abilene, Kansas.

8 It is significantly of note that several of the above-identified elements used in the process
9 of manufacturing Perlite wallboard as set forth in this specification are likewise in use in current
10 gypsum board line equipment. Thus, the present apparatus not only provides a new and unique
11 system for manufacturing Perlite wallboard, but also provides a means by which an existing
12 gypsum wallboard manufacturing facility may be easily and readily transformed into a Perlite
13 wallboard manufacturing facility. Thus, by making minor modifications to a traditional gypsum
14 wallboard production facility, and by adding the additional equipment listed above (e.g.,
15 secondary expanded Perlite feed tank, adhesives storage equipment, mixing equipment, and the
16 optional initial heat treatment tunnel and duct work interconnecting the heat treatment tunnel to
17 the standard kiln air recycling system) to an existing gypsum boardline, an existing gypsum
18 wallboard manufacturing facility may be smoothly and economically transitioned into a
19 manufacturing facility for the improved wallboard of the instant invention, without the
20 investment costs of building an entirely new production plant.

21
22 Examples

The following examples employing the instant invention proved to bring very favorable test results.

EXAMPLE 1

The following is an example of post addition of polyvinyl alcohol to the formulation of the instant invention. A 6 inch by 6 inch by 1/2 inch sample is prepared using the following formulation:

Materials	Weight in Ounces	Weight by Percentage	Preferred
Gypsum	5.80	42-50%	45.224%
Perlite	0.30	1-3%	2.339%
Board Starch	0.05	0.3-0.6%	0.389%
Accelerator	0.03	0.1-0.3%	0.233%
Boric Acid	0.01	0.01-0.15%	0.077%
Vinyl Acetate	0.30	0.8-4%	2.339%
Polyvinyl Alcohol	0.035	0.1-0.3%	0.272%
Lignosite (dispersant)	0.10	0.07-0.8%	0.779%
Ethoxysulfate (soap)	0.10	0.07-0.8%	0.779%
Water	6.10	42-48%	47.569%

First, the dry constituents, gypsum, perlite, board starch, accelerator, and boric acid are blended until a homogenous mixture is obtained. Next, in a separate vessel, the vinyl acetate and polyvinyl alcohol and dispersant are mixed together with 2/3 of the total water and the remaining 1/3 of the total water is combined with the soap foaming agent and blended to achieve 1/4 inch diameter bubbles of foam. Finally, all of the constituents are combined in a laboratory mixer and blended until 100% of a slurry is obtained. The slurry is then poured into a paper envelope comprising fire resistant and water repellant construction board cover sheets and formed and sealed. After hydration occurs, the sample is placed into a small laboratory kiln to drive off the excess water and dry the board example. The test results for this composition passed ASTM C36 specification.

1
2 EXAMPLE 2

3 It has been found that sodium trimetaphosphate may be utilized to increase compressive
4 strength by enhancing cylindrical needle-like crystal growth in the core of the improved
5 strengthened construction board of the instant invention. Sodium trimetaphosphate is a
6 combination of earth metals and is known by the chemical equation $(\text{NaPO}_3)_3$. This compound
7 may be added to the slurry either in solution or in a dry powder state, although in solution is
8 preferred. By adding sodium trimetaphosphate into the system, the favorable long cylindrical
9 crystal growth that adds the most strength to the core of the construction board and also enhances
10 the paper to core bond is greatly increased, and the result is higher compressive strength. The
11 compound is highly water soluble and dilutes very quickly allowing it to disperse very rapidly.
12 The resultant chemical reaction is not entirely understood, although it is believed that the sodium
13 hydroxide and fluoride in the sodium trimetaphosphate reacts with the calcium in the gypsum
14 and increases the crystal growth. The following is an example of the addition of sodium
15 trimetaphosphate to the formulation of the instant invention. A 6 inch by 6 inch by $\frac{1}{2}$ inch
16 sample is prepared using the following formulation:

1	Materials	Weight in Ounces	Weight by Percentage	Preferred
2				
3	Gypsum	6.70	42-50%	47.857%
4	Perlite	0.25	1-3%	1.785%
5	Board Starch	0.05	0.3-0.6%	0.357%
6	Ball Mill Accelerator (bma)	0.02	0.1-0.3%	0.142%
7	Boric Acid	0.005	0.01-0.15%	0.035%
8	Vinyl Acetate	0.15	0.8-4%	1.071%
9	Polyvinyl Alcohol	0.03	0.1-0.3%	0.214%
10	Sodium Trimetaphosphate	0.095	0.01-0.7%	0.678%
11	Ethoxysulfate (soap)	0.10	0.07-0.8%	0.714%
12	Lignosite (dispersant)	0.10	0.07-0.8%	0.714%
13	Water	6.50	42-48%	46.433%

14 First, the dry constituents, gypsum, Perlite, board starch, bma, and boric acid are blended
 15 until a homogenous mixture is obtained. Next, in a separate vessel, the vinyl acetate and
 16 polyvinyl alcohol and dispersant are mixed together with 2/3 of the total water and the remaining
 17 1/3 of the total water is combined with the soap foaming agent and the sodium trimetaphosphate
 18 and blended to achieve 1/4 inch diameter bubbles of foam. Finally, all the constituents are
 19 combined in a laboratory mixer and blended until 100% of a slurry is obtained. The slurry is
 20 then poured into a paper envelope comprising fire resistant and water repellant construction
 21 board cover sheets and formed and sealed. After hydration occurs the sample is placed into a
 22 small laboratory kiln to drive off the excess water and dry the board sample. The test results for
 23 this composition satisfied the criteria of ASTM methods C-36 and C-473.

EXAMPLE 3

Materials	Weight in pounds per MSF	Weight by %	Preferred
Perlite	60	1-3%	2.564%
Calcined gypsum	1130	42-50%	48.295%
Ball mill accelerator	7.0	0.1-0.3%	.299%
Starch	9.0	0.3-0.6%	.384%
Boric Acid	.25	0.01-0.15%	.015%
Sodium Trimetaphosphate	.50	0.01-0.7%	.021%
Fiberglass fibers	1.5	0.1-0.2%	.064%
Dispersant (lignosulfonate)	2.0	0.07-0.8%	.085%
Soap (foamer)	1.5	0.07-0.8%	.064%
Vinyl Acetate	28.0	0.8-4%	1.196%
Water	1100	42-48%	47.013%

This example discloses a composition reflecting the most preferred embodiment of the improved construction board composition of the instant invention, and continues the study of the addition of various percentages of calcium sulfate into the composite core. It is also a test of an adhesive formulation comprising vinyl acetate polymer emulsion, modified starch, and boric acid. In this test, the first step was to mix about 15% of the preferred Perlite of the invention with the remaining dry constituents. The Perlite 15% (by volume) was combined with modified starch, ball mill accelerator, boric acid, and about 25% (by volume) calcium sulfate. Next, about 5% (by volume) vinyl acetate emulsion was added to soap foam, dispersant and about 50% (by volume) water. The wet and dry ingredients are fed by normal board manufacturing line apparatus into a pin mixer for 3 seconds. The slurry is dispersed onto continuous moving paper cover sheets. The construction board is formed and conveyed to the cutting knife. The board set up fairly hard in under three minutes and was then cut to desired lengths. The board was then inverted and run through a kiln at normal drying temperature parameters for about an hour. Once cooled, the sample was weighed and measured and the results were catalogued. Several days

later this sample was conditioned and then tested to ASTM C473 standards. Test results confirmed nearly double those of the gypsum core control sample in nail pull resistance, edge hardness, and with improved flexural strength.

EXAMPLE 4

Materials	Weight in Ounces	Weight by %	Preferred
Gypsum	10.0	48-55%	51.355%
Ball Mill Accelerator	.05	0.1-0.3%	.244%
Starch	.08	0.3-0.6%	.387%
Boric Acid	.02	0.01-0.15%	.096%
Potassium sulfate	.01	0.05-0.3%	.048%
Lignosulfonate(dispersant)	.01	0.07-0.8%	.048%
Soap (foamer)	.02	0.07-0.8%	.096%
Vinyl Acetate	.35	0.8-4%	1.697%
Water	9.5	42-48%	46.029%

This example discloses the addition of the unique adhesive formulation of the instant invention into traditional gypsum board without an expanded mineral added. Calcium sulfate(gypsum), starch, ball mill accelerator, potassium sulfate, and boric acid were combined in the above amounts. Then, lignosulfonate, Ethoxysulfate, vinyl acetate, and water were combined and mixed into a foamy consistency and combined with the dry ingredients. The mixture was mixed at high speed and then poured into a 6" by 12" form with a construction board paper insert and sealed and formed into a sheet identical to traditional gypsum board. The sample was then removed from the form and the set was timed. After timing the set and allowing the full hydration set to occur, the sample was then heated in a kiln at 180°F to evaporate excess water. Once dry, these boards were left to cure for two days and then tested. These experiments were conducted to evaluate increased strength in traditional construction board compositions with the addition of the synthetic binder. Nail pull resistance, edge hardness, and flexural strength were

increased 150% in all the samples that were made and tested. This decrease in set time and increase in strength of the construction board can allow for increased operating speeds in current board manufacturing facilities. Varying curing temperatures were applied in this example from 75°C to 352°C with favorable test results, including passing nail pull resistance, flexural breaking loads, edge hardness, and humidified bond according to ASTM C36. However, the preferred curing temperatures ranged from 79°C to 275°C.

EXAMPLE 5

Materials	Weight in Ounces	Weight by %	Preferred
Perlite	.40	1-3%	2.366%
Gypsum	8.0	42-50%	47.281%
Ball mill accelerator	.04	0.1-0.3%	.238%
Starch	.07	0.3-0.6%	.413%
Boric acid	.015	0.01-0.15%	.088%
Potassium sulfate	.015	0.05-0.3%	.088%
Dispersant	.02	0.07-0.8%	.118%
Soap (foamer)	.01	0.07-0.8%	.059%
Vinyl Acetate	.35	0.8-4%	2.068%
Water	8.0	42-48%	47.281%

In this example, first the dry ingredients were combined together and blended until a homogeneous mix was achieved, these dry ingredients being plaster grade expanded perlite with a loose density of 6 to 8 pounds per cubic foot, calcined gypsum stucco, starch, ball mill land plaster accelerator, pot ash and boric acid. Secondly, the dry lignosite dispersant was combined with the water and mixed until blended. Thirdly, the soap water and vinyl acetate were combined together and blended with an electric mixer to generate foam or bubbles. The soap water and vinyl acetate foam mix was then added to the lignosite and water and then all the wet ingredients were combined with the dry blended ingredients and mixed by hand for about 15 seconds to achieve 100% of a slurry. The ambient temperature was 82°F and the surrounding

1 humidity was 29%. This slurry was then poured into a fire resistant and water repellant
2 construction board paper insert or envelope to make a 1/2 inch thick board sample measuring 6
3 inches by 6 inches. The back sheet of the insert was then sealed to the face sheet folds using a
4 starch based drywall edge paste, formed, and then removed from the form, and the initial or snap
5 set was timed and recorded. In a typical drywall manufacturing process there are two different
6 sets, first being the initial or snap set, whereas the continuous board hardens or stiffens
7 sufficiently to be cut into desired lengths downstream at the rotary knife. The secondary or
8 hydration set relates to the complete hydration of the gypsum crystals, meaning the amount of
9 time sufficient to rehydrate the calcined gypsum, replacing the two molecules of H₂O removed
10 during the calcining process of land plaster. This secondary hydration set can be from as low as
11 4.6 minutes to as high as 7 minutes depending on the grind and purity of the land plaster being
12 utilized. At 2 1/2 minutes the sample of the above example was cut cleanly and inspected. The
13 inspection revealed that the slurry had sufficiently set and it is believed that the chemical
14 reaction of the synthetic binder (vinyl acetate) and the calcined gypsum allows the gypsum
15 crystal to rehydrate more rapidly than calcined gypsum rehydrated without the synthetic additive
16 of the present invention. The above process has been duplicated repeatedly in the lab with slight
17 variations in formula achieving the same results. A range of volumes of the preferred synthetic
18 binder (vinyl acetate) were tested with gypsum and consistently set times were reduced over
19 those of the gypsum control samples with no synthetic additives, and consistently stronger
20 samples were obtained over those of the gypsum control samples with no synthetic additives.
21 All procedures including the drying of the samples were consistent with typical drywall
22 manufacturing processes. The excess water in the samples was driven off by placing samples in

a laboratory kiln with access to moving heated air at a temperature of between 150°C and 200°C for a period of 50 minutes to 1 hour.

EXAMPLE 6

Materials	Weight in Ounces	Weight by %	Preferred
Perlite	.30	1-3%	1.816
Gypsum	8.0	42-50%	48.434
Starch	.075	0.3-0.6%	.454
Ball mill accelerator	.037	0.1-0.3%	.224
Boric acid	.015	0.01-0.15%	.090
Dispersant	.020	0.07-0.8%	.121
Soap (foamer)	.020	0.07-0.8%	.121
Non-V.O.C. acrylic polymer	.35	0.8-4%	2.119
Water	7.7	42-48%	46.618

This example discloses the other preferred unique adhesive formulation of the instant invention into traditional gypsum board. Calcium sulfate(gypsum), starch, ball mill accelerator, and boric acid were combined in the above amounts. Then, lignosulfonate, Ethoxysulfate, non-V.O.C. acrylic emulsion, and water were combined and mixed thoroughly and was then combined with the dry ingredients. The mixture was mixed at high speed and then poured into a 6" by 12" form with a construction board paper insert and sealed and formed into a sheet identical to traditional gypsum board. The sample was then removed from the form and the set was timed. After timing the set and allowing the full hydration set to occur, the sample was then heated in a kiln at 180°F to evaporate excess water. Once dry, these boards were left to cure for two days and then tested. These experiments were conducted to evaluate increased strength in traditional construction board compositions with the addition of the synthetic binder. The resulting board samples of this particular example surpassed all ASTM C36 specifications. The test results for this composition satisfied the criteria of ASTM methods C-36 and C-473.

EXAMPLE 7

Materials	Weight in Ounces	Weight by %	Preferred
Gypsum	990.0	42-50%	48.072%
Expanded Perlite	50.0	1-3%	2.427%
Starch	10.0	0.3-0.6%	0.485%
Ball mill accelerator	4.0	0.1-0.3%	0.194%
Potassium sulfate	2.75	0.134%	0.05-0.3%
Boric acid	0.25	0.01-0.15%	0.013%
Foaming Agent	1.50	0.07-0.8%	0.073%
Sodium Trimetaphosphate	0.50	0.01-0.7%	0.024%
Ethoxilated Alcohol	0.40	0.01-0.7%	0.019%
Vinyl Acetate Emulsion	28.0	0.8-4%	1.359%
Diloflo (Naphthalene Sulfonate)	2.0	0.07-0.8%	0.099%
Water	970.0	42-49%	47.101%

This example discloses the addition of a straight chain linear ethoxilated alcohol, added to the synthetic binder in a blend prior to its introduction into the system of this invention. By adding the nonionic surfactant to the binder, the polymer has greater dispersion capabilities in the slurry and forms strong or strengthened air entrainment into the matrix. The wetting action of the nonionic surfactant when blended with the polymer also decreases the amount of water needed to achieve a workable slurry. This example exemplifies the most preferred formulation of this invention. The system as a whole will achieve construction board weights up to 40 percent lighter and meets all ASTM standards for C36 gypsum wallboard specifications. This formulation is for use in production runs of the invention and is measured in units per thousand square feet typical to industry practice. The dry ingredients are fed into a mixing conveyor screw from their respective feeders and blended while being conveyed to the pin mixer. The wet ingredients, with the exception of the foam, are blended and fed into the water system upstream of the pin mixer to achieve proper dispersion. The formed construction board is then conveyed on a belt to the knife during which time it has set to a hardness sufficient to be cut at the knife.

1 After being cut into the desired lengths it is inverted and run through a multi deck board drying
2 kiln. The resulting dry construction board is stacked and housed for shipment to consumers. All
3 of the construction board of this example met or exceeded nail pull resistance, flexural breaking
4 loads, core and edge hardness, and deflection as well as humidified bond requirements per
5 ASTM C36.